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Marine Physical Laboratory

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Bio-Optical Imaging System

Jules S. Jaffe

Final Report to the
Office of Naval Research
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University of California, San Diego
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The funding for this work was used to construct an advanced underwater optical imaging system. The optical system was used in concert with our existing 3-dimensional sonar imaging system to obtain in-situ ground truth about the identical animals that we were sensing with our sonar device. This project studied and developed advanced optical techniques whose long term goal was to advance the state of the art in-situ remote sensing of pelagic animals sections.

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Abstract

The funding for this work was used to construct an advanced underwater optical imaging system. The optical system was used in concert with our existing 3-dimensional sonar imaging system to obtain *in-situ* ground truth about the identical animals that we were sensing with our sonar device. This project studied and developed advanced optical techniques whose long term goal was to advance the state of the art *in-situ* remote sensing of pelagic animals sections.

Long-Range Scientific Objectives

The long range scientific objectives of our program are to develop and utilize the "next generation" of underwater in-situ remote sensing tools for measuring both biological and physical phenomena. An increased understanding of many oceanographic phenomena will only be possible through these efforts. This includes the pursuit of the understanding of the physics of the propagation of sound and optics in the ocean so that the advantages and disadvantages of different strategies can be weighed, the development of mathematical inversion techniques, and the construction and utilization of such devices.

Research Objectives

The near term objectives of this program are to advance our understanding of how light can propagate in a horizontally stratified environment so that an accurate model which predicts the outcome of an underwater imaging experiment can be obtained. We also would like to use our newly developed Monte Carlo model in order to explore issues with other Ocean Optics investigators (Voss and Maffione) to look at the validity of computing the absorption coefficient from an isotropic source. The other major area that we are exploring is the utilization of structured lighting techniques in order to measure data from which the 3-dimensional inherent optical parameters of the medium can be computed.

Research Approaches

Our technique for understanding both the propagation of light in a stratified environment and also the evaluation of the validity of the absorption meter (developed by Voss and Moffione) is to run a Monte Carlo model that we have developed. This model predicts radiance on the surface of a sphere which is equidistant from an omnidirectional point source. In the case of the 3-dimensional imaging system, we will be packaging our source and camera system this year and deploying the system in the water. In addition, we are constructing a multispectral version of the system so that we can gain more information about the organisms that we are imaging.

Research Results

During the last year, we have completed work on the evaluation of the linearization assumptions and we very well understand the limitations of the small angle approximation in contrast to the more correct results that the Monte Carlo model predicts. In addition, we have been able to conclude a series of lab tests which verify the performance characteristics of the 3-dimensional imaging system.

The major new results from this year concern the validation and testing of the 3-dimensional imaging system. Together with student A. Palowitch, we have completed the theoretical justification for the forward model which includes a linearization step from which the inverse procedure pretty much "falls out". Extensive computer simulations have validated both the uniqueness and also the stability of the inverse. In addition, in a series of lab tests using different concentrations of chlorophyll-a, the performance of the system has been validated

Accomplishments

I believe that the development and validation of our new 3-dimensional imaging system has potential to be an important advance for the field of underwater optics. As we have shown, it is possible to achieve measurements of inherent optical parameters in volumes without disturbing the media. What is the small scale structure of the ocean with respect to optical properties? Using our method, one can now start to answer this question.

Publications from ONR Sponsored Work

1. Jaffe, J.S., "Robotic sensors: acoustic and optical options," in **Acoustic Signal Processing for Ocean Exploration**, edited by Jose M.F. Moura and Isabel M.G. Lourtie (NATO ASI SERIES, Kluwer Academic Publishers, Portugal, 1993), pp. 581-587.
2. Jaffe, J.S., "Three-dimensional Imaging Overview", In **"Three-dimensional Animal Aggregations: Mechanisms and Functions"**, J.K. Parrish, W. M. Hamner and C.T. Prewitt (editors) In Press- U. C. Press, to appear, 1993.
3. Jaffe, J.S., "Monte Carlo modeling of underwater image formation: validity of linear and small angle approximations," Applied Optics (accepted subject to revision).
4. Palowitch, A. W. and Jaffe, J.S., "Determination of three dimensional ocean chlorophyll distribution from underwater serial sectioned fluorescence images". (Accepted for publication, Applied Optics).
5. Palowitch, A. W. and Jaffe, J.S., "Experimental Validation of a 3-dimensional imaging system". (To be submitted to special issue, JGR).
6. Maffione, R. A., Jaffe, J.S., and Voss,K.J., "Comparison of Theory, Measurements, and a Monte Carlo Model of the Irradiance Distribution from an Isotropic Source in the Ocean and the Determination of the Absorption Coefficient". (To be submitted to Applied Optics)

Patent

1. J. S. Jaffe, "A multi-aperture imaging device," U.S. Patent Pending, Marine Physical Laboratory of the Scripps Institution of Oceanography. (Submitted).

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